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NRL Report 7951

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Radar Cross Sections of the T-38 Aircraft for the Head-On Aspects in L, S, and X Bands

F. D. QUEEN

Target Characteristics Branch
Radar Division

January 8, 1976

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The radar cross sections of a T-38 aircraft were determined for nose-on aspects using the NRL dynamic area measurement system. The 20, 50, and 80 percentile values of the radar cross section distribution function were tabulated. Left-circular polarization was transmitted at 9225 MHz, and the parallel and orthogonal components were received. Vertical polarization was used on transmission and reception for 2800 MHz and 1300 MHz. The RCS for the nose-on aspect can vary as much as 3 dB between runs, because the aircraft rarely holds a constant
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20. ABSTRACT (Continued)

aspect with respect to the radar from run to run, or during a run. When the aspect cell size is limited to ±1.0 degree, the median radar cross sections are shown to be 0.8 m^2 for the X-band left circular return, 3.1 m^2 for 2800 MHz, and 1.8 m^2 for 1300 MHz.

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CONTENTS

RADAR CROSS SECTIONS OF THE T-38 AIRCRAFT FOR THE HEAD-ON ASPECTS IN L, S, AND X BANDS

INTRODUCTION

The radar cross sections of a standard T-38 aircraft with no external loading were determined using the NRL dynamic area measurement system (Appendix A). The aspect-angle coverage was limited to directly head-on (A = 0°, E = 0°), and head-on for elevation angles of 6 to 24 degrees below the aircraft. Left circular polarization was transmitted at 9225 MHz, and the parallel and orthogonal components were received. The designation X_{LL} and X_{LR} is used, where X denotes X band, the first subscript denotes transmitted polarization, and the second subscript denotes the received polarization. For 2800 MHz and 1300 MHz vertical polarization was used on transmission and reception.

DATA ACQUISITION

Data were taken using two types of courses on the same radial. One was a constant-angle dive from 4000 feet, and the second was a level course at 2500 feet. Due to haze over the water and the small size of the aircraft, optical acquisition was not possible at ranges greater than 6 kiloyards without the aid of the aircraft landing light. This allowed acquisition at 14 kiloyards but meant that the initial portion of each data run did not meet the configuration requirements. The landing gear and light were secured by the time the aircraft was 8 kiloyards from the radar, so that about 40 seconds of useful data were acquired from each run.

Calibration spheres were released prior to and at the conclusion of each flight. The worst-case error which could be attributed to the differences between calibrations was 0.3 dB for data runs between runs 1078 and 1086 for the X_{LL} component. For the remainder of the runs the differences between pre- and postflight calibrations were less than 0.06 dB. The maximum difference in calibrations over the four-flight interval was 1.0 dB for L and S bands and 0.6 dB for X_{LL}.

DATA REDUCTION

The data reduction is described in Appendix B. Briefly, the process consists of determination of the azimuth and elevation aspects as a function of time during the data run, generating a pulse-by-pulse tape of the radar cross section (RCS), and segmenting this tape according to aspect angle to form a distribution function from which the percentiles can be read.

Note: Manuscript submitted November 4, 1975.

The pulse-by-pulse tape of calibrated RCS values is generated by processing each received pulse in accordance with the equation

$$\sigma = \sigma_s \left(\frac{R_m}{R_s}\right)^4 \left(\frac{\alpha_m}{\alpha_s}\right) \left(\frac{E_m}{E_s}\right)^2,$$

where

σ is the aircraft RCS,

σ_s is the RCS of the sphere,

E_s is the voltage produced by the sphere,

R_s is the range to the sphere,

α_s is the attenuation in the receiver for the sphere measurement,

E_m is the voltage produced by the target,

R_m is the range to the target, and

α_m is the attentuation in the receiver during the target measurement.

RESULTS

The results of the measurement are contained in Tables 1 through 5. The 20, 50, and 80 percentiles of the RCS distribution function are listed for each of 15 dive courses and five level courses. A weighted average is given for the dive courses which is determined by

$$\frac{\Sigma\, \eta_i\, \sigma_i}{\Sigma\, \eta_i},$$

where

η_i is the number of pulses received in an aspect interval and

σ_i is the RCS (m^2) corresponding to the aspect interval.

Table 1 lists the RCS for all data falling in an aspect cell in which the aircraft's deviation from directly head-on is less than ±1.0 degree. Table 2 contains the data which fall within ±2.0 degrees in azimuth and elevation from directly head-on. Table 3a lists the RCS for a nose-on azimuth aspect with a varying elevation aspect broken into 2.0-degree cells, and Table 3b contains the weighted averages of the X-band data. The portion of the data runs where the landing gear was extended, was processed and is given in Table 4. During some early data runs at the constant altitude, crabbing of the aircraft was experienced. Since the pilot held a constant radial, the crab angle remained constant. The X_{LL} RCS values for angles of 2, 5, and 7 degrees were obtained from these runs and are shown in Table 5.

Examination of the tables shows that when viewing the T-38 near head-on, as much as 3 dB variation between runs can be expected. This is because the aircraft is rarely holding a constant aspect with respect to the radar from run to run, or during a data run.

Table 1
RCS at 9225 MHz (X Band), 2800 MHz (S Band), and 1300 MHz (L Band) for the Head-On Aspect for a ±1.0-Degree Cell Size (azimuth and elevation deviation from directly head-on)

Run	20, 50, and 80 Percentiles of the RCS (m^2)											
	X Band With Left Circular Polarization Transmitted and Received (X_{LL})			X_{LR}			S Band With Vertical Polarization Transmitted and Received (S_{VV})			L_{VV}		
	20	50	80	20	50	80	20	50	80	20	50	80
1101	0.33	0.84	1.7	0.22	0.58	1.3	1.8	4.0	6.9	1.7	2.0	2.2
1102	0.56	1.3	2.6	0.20	0.49	1.0	2.0	3.7	5.3	1.2	1.5	1.8
1103	0.28	0.72	1.4	0.13	0.40	1.0	2.2	4.6	5.8	1.5	1.8	2.2
1104	0.23	0.71	1.4	0.21	0.61	1.2	1.8	2.4	2.8	1.5	1.8	2.0
1092	0.25	0.60	1.3	0.29	0.60	1.3	0.6	1.0	2.9	1.5	2.0	2.8
Weighted Average	0.33	0.83	1.7	0.21	0.53	1.2	1.6	3.1	4.7	1.5	1.8	2.2

Table 2
RCS for the Head-On Aspect for a ±2.0-Degree Cell Size

Run	20, 50, and 80 Percentiles of the RCS (m^2)											
	X_{LL}			X_{LR}			S_{VV}			L_{VV}		
	20	50	80	20	50	80	20	50	80	20	50	80
1092	0.22	0.58	1.2	[illegible]	0.48	1.0	0.26	0.76	1.7	1.5	2.0	2.9
1093	0.16	0.44	0.96	0.11	0.39	1.1	0.29	0.99	2.5	1.0	1.8	2.6
1094	0.22	0.57	1.3	0.40	1.1	1.7	0.54	0.82	1.2	2.3	2.8	3.2
1096	0.34	0.84	1.6	0.26	0.75	1.7	0.54	0.85	1.8	1.6	2.2	2.6
1097	0.20	0.66	1.2	0.21	0.58	1.3	0.18	0.66	1.2	0.84	1.9	2.4
1098	0.36	0.78	1.5	0.26	0.67	1.3	0.61	1.0	1.5	2.3	2.9	3.5
1101	0.28	0.91	2.0	0.20	0.64	1.4	1.6	2.2	3.5	1.4	1.7	2.2
1101	0.27	0.67	1.4	0.22	0.57	1.3	0.64	1.7	5.0	1.4	1.5	2.2
1102.	0.32	0.88	2.1	0.24	0.64	1.3	1.5	2.4	4.2	1.1	1.4	1.8
1103	0.35	0.88	1.7	0.22	0.59	1.4	1.1	2.4	4.7	1.3	1.6	2.0
1104	0.42	1.0	2.0	0.18	0.50	1.0	1.5	2.5	4.3	1.4	1.8	2.2
1105	0.39	1.0	2.2	0.28	0.81	1.7	0.62	1.7	3.1	[illegible]	—*	—*
1106	0.42	1.0	2.1	0.21	0.55	1.2	1.1	1.4	2.7	[illegible]	1.4	1.8
1107	0.50	1.2	2.7	0.25	0.48	0.83	1.1	1.5	4.1	1.2	1.3	1.5
1107	0.22	0.71	1.7	0.22	0.93	2.0	0.16	0.48	0.92	2.0	2.3	2.5
1108	0.34	0.89	1.8	0.21	0.44	0.80	0.84	1.4	3.4	0.01	1.1	1.3
1108	0.29	0.88	1.6	0.58	1.5	2.5	0.90	1.2	2.1	1.9	2.3	2.6
1109	0.14	0.44	1.1	0.14	0.48	1.2	0.66	1.2	2.1	3.2	0.61	1.3
Weighted Average	0.29	0.78	1.6	0.22	0.62	1.3	0.77	1.5	2.9	1.3	1.8	2.3

*No data.

Table 3a
RCS for the Head-On Azimuth Aspect (±1.0 degree) and a Profile of Elevation Aspects (±1.0 degree)

Elev. Angle (deg)	20, 50, and 80 Percentiles of RCS (m^2)											
	X_{LL}			X_{LR}			S_{VV}			L_{VV}		
	20	50	80	20	50	80	20	50	80	20	50	80
Run 1085												
6	0.32	0.94	2.1	0.15	0.63	1.6	1.0	2.4	3.3	—*	—*	—*
8	0.55	1.5	3.2	0.44	1.3	2.6	0.62	2.3	4.0	—*	—*	—*
10	0.56	1.6	3.6	0.30	0.85	1.8	0.85	1.3	1.7	—*	—*	—*
12	0.26	0.84	2.2	0.28	0.76	1.5	0.27	1.8	2.6	—*	—*	—*
14	0.27	0.82	1.7	0.14	0.38	0.86	0.27	1.2	2.4	5.2	7.1	9.3
16	0.32	1.0	1.9	0.17	0.49	1.1	0.69	2.2	9.6	2.1	2.8	4.1
18	0.15	0.39	0.87	0.10	0.26	0.52	0.88	1.3	2.4	0.80	1.5	2.1
20	0.18	0.63	1.2	0.10	0.31	0.72	0.24	1.6	4.1	0.29	1.3	2.5
22	0.14	0.38	0.85	0.12	0.34	0.64	1.1	2.2	3.1	5.5	7.2	8.9
24	0.26	0.66	1.5	0.10	0.36	0.79	0.60	3.2	7.3	2.7	8.0	14
Run 1088												
6	0.20	0.64	1.6	0.34	1.0	2.1	0.98	2.5	4.1	0.18	0.64	1.3
8	0.38	1.1	2.2	0.43	1.1	2.3	0.61	1.0	2.7	4.0	5.5	9.6
10	0.33	0.96	2.3	0.13	0.34	0.83	0.12	0.40	1.7	1.3	2.4	3.6
12	0.26	0.64	1.3	0.16	0.46	0.98	0.10	0.10	0.17	0.77	1.0	2.3
14	0.16	0.49	1.1	0.25	0.66	1.3	0.29	0.60	0.96	0.52	1.5	2.4
16	0.22	0.62	1.2	0.16	0.44	0.92	0.18	0.36	0.83	0.76	4.8	7.4
18	0.16	0.50	1.1	0.22	0.61	1.3	0.16	0.76	1.4	0.72	1.1	2.1
20	0.12	0.31	0.75	0.10	0.23	0.67	0.57	2.4	4.6	0.90	1.4	1.7
22	0.11	0.30	0.66	0.18	0.56	1.1	0.18	1.9	3.1	0.52	0.81	1.4
24	0.14	0.44	1.3	0.11	0.32	0.68	0.51	1.8	2.9	0.78	4.6	7.6
Run 1089												
6	0.25	0.68	1.5	0.16	0.59	1.3	1.4	2.4	4.1	0.11	0.23	0.53
8	0.28	0.92	2.0	0.20	0.68	1.8	1.4	2.9	4.8	0.14	0.35	1.4
10	0.75	2.0	3.7	0.28	0.73	1.3	0.66	1.2	2.0	0.31	4.4	7.0
12	0.18	0.54	1.2	0.16	0.42	0.90	0.10	0.26	0.59	1.2	2.9	3.8
14	0.18	0.52	1.0	0.11	0.30	0.63	0.38	0.65	1.2	0.93	1.4	2.4
16	0.20	0.49	1.1	0.22	0.49	0.88	0.16	0.52	1.5	0.35	0.92	2.7
18	0.10	0.24	0.61	0.29	0.66	1.1	0.33	0.79	2.4	2.4	5.0	7.5
20	0.17	0.53	1.2	0.10	0.26	0.49	0.66	1.3	2.0	0.50	1.7	2.3
22	0.19	0.48	0.95	0.10	0.22	0.48	0.97	1.4	2.3	0.54	0.96	1.4
24	0.12	0.46	1.0	0.12	0.26	0.51	0.91	1.4	1.7	2.9	4.6	7.4
Run 1090												
6	0.14	0.44	1.1	0.20	0.67	1.6	1.2	2.7	4.0	0.18	0.60	0.99
8	0.46	1.3	2.5	0.42	1.3	2.6	0.91	5.1	7.2	0.10	0.23	0.96
10	0.40	0.99	1.9	0.48	1.1	2.1	0.31	0.63	0.77	1.4	3.6	4.8
12	0.21	0.57	1.6	0.16	0.46	0.93	0.31	0.76	1.3	0.91	1.3	1.7
14	0.24	0.66	1.3	0.10	0.24	0.50	0.41	1.2	2.2	2.6	7.3	8.3
16	0.22	0.63	1.3	0.18	0.54	1.1	0.80	1.4	8.3	3.1	3.6	5.0
18	0.10	0.30	0.67	0.10	0.33	0.73	0.54	0.67	1.0	1.3	2.2	3.5
20	0.10	0.34	0.78	0.10	0.26	0.53	0.78	1.5	2.4	1.3	2.7	4.3
22	0.10	0.27	0.68	0.10	0.27	0.67	0.57	1.3	2.8	0.22	0.84	1.8
24	0.23	0.65	1.1	0.12	0.28	0.63	—*	—*	—*	—*	—*	—*
Run 1110												
6	—†	—†	—†	—†	—†	—†	—†	—†	—†	—†	—†	—†
8	0.36	0.93	1.8	0.34	1.0	2.0	1.3	3.3	5.2	0.10	0.32	1.0
10	0.58	1.5	3.1	0.58	1.2	2.2	0.76	1.8	3.2	5.8	7.1	8.1
12	0.30	0.90	2.3	0.28	0.76	1.6	1.9	2.9	3.7	0.99	1.6	2.3
14	0.78	1.5	2.2	0.21	0.50	0.87	0.26	0.71	1.2	3.4	4.2	5.4
16	0.30	0.84	2.0	0.12	0.32	0.70	0.29	0.52	3.2	4.8	7.7	8.5
18	0.23	0.72	1.6	0.19	0.50	1.1	0.45	0.88	1.7	1.6	2.1	2.9
20	0.11	0.40	1.0	0.11	0.33	0.73	0.74	1.6	4.5	1.2	2.4	3.2
22	0.29	0.86	1.9	0.12	0.44	0.92	1.1	1.8	3.8	0.26	0.62	1.3
24	0.31	0.98	1.9	0.21	0.56	1 2	0.79	1.1	2.5	1.7	6.1	13

*No data.
†Gear down.

Table 3b
Weighted Averages of the Five X-Band Runs Listed in Table 3a

Elev. Angle (deg)	20, 50, and 80 Percentiles of RCS (m^2)					
	X_{LL}			X_{LR}		
	20	50	80	20	50	80
6	0.23	0.68	1.6	0.22	0.73	1.7
8	0.41	1.2	2.4	0.36	1.1	2.3
10	0.54	1.4	3.0	0.35	0.82	1.6
12	0.24	0.70	1.8	0.21	0.58	1.2
14	0.32	0.79	1.4	0.17	0.43	0.86
16	0.25	0.72	1.5	0.17	0.45	0.93
18	0.15	0.43	0.97	0.18	0.47	0.96
20	0.13	0.43	0.96	0.10	0.28	0.61
22	0.16	0.45	1.0	0.13	0.37	0.78
24	0.22	0.65	1.5	0.14	0.39	0.83

Table 4
RCS for the Head-On Aspect with Landing Gear Extended

Run	20, 50, and 80 Percentiles of RCS (m^2)											
	X_{LL}			X_{LR}			S_{VV}			L_{VV}		
	20	50	80	20	50	80	20	50	80	20	50	80
1093	0.18	0.97	2.8	0.35	0.88	3.1	0.18	0.72	2.0	2.8	4.0	6.4
1096	0.35	0.96	2.4	0.14	0.72	2.0	0.34	1.2	2.6	1.7	6.2	9.4
1097	0.16	0.52	1.5	0.14	0.49	1.3	0.18	0.65	1.8	0.32	0.97	1.7
1098	0.24	0.96	2.5	0.33	1.4	4.0	0.10	0.24	0.98	0.08	3.1	4.3
1101	0.21	0.86	2.5	0.20	0.59	1.2	1.0	3.0	4.3	—*	—*	—*
1102	0.56	1.7	3.2	0.26	0.96	2.2	1.4	2.7	5.2	0.30	1.1	3.3
1103	0.64	2.0	4.1	0.23	0.62	1.5	1.3	1.9	3.3	0.42	1.4	3.3
1104	0.54	1.7	3.6	0.39	0.95	2.0	0.70	2.8	8.2	3.0	5.4	6.2
1105	0.86	2.2	4.4	0.30	0.86	1.9	0.97	2.0	3.4	—*	—*	—*
1106	0.61	1.7	3.6	0.22	0.78	3.0	1.9	3.1	5.1	0.59	2.0	5.4
1107	0.86	2.3	4.8	0.20	0.64	2.0	1.9	3.7	7.1	0.41	1.5	3.6
1108	0.64	2.3	5.7	0.26	0.81	2.0	1.8	3.1	6.1	0.28	1.0	2.8
1109	0.66	1.7	3.4	0.22	0.72	1.7	1.8	3.4	5.4	0.62	2.0	3.9
Weighted Average	0.53	1.6	3.5	0.24	0.80	2.1	1.1	2.3	4.4	0.99	2.6	4.5

*No data.

Table 5
Median RCS for the X_{LL} Components
for Azimuth Aspects of
2, 5, and 7 degrees

RCS (m^2) for Azimuth Aspects of 2, 5, and 7 degrees			
Elev. Angle	2	5	7
6	0.61	0.99	0.82
8	0.94	1.7	2.2
10		3.1	1.4
12	.0	1.6	2.1
14	0.60	0.63	1.5
16	0.45	0.90	1.2
18	0.44	1.3	0.84
20	0.52	0.63	0.64
22	0.66	1.1	1.1

Comparison of the weighted averages of the ±1.0-degree cell with the ±2.0-degree cell shows no change in X_{LL} and L_{VV} values but an increase for S_{VV} and a decrease for X_{LR}.

A detailed investigation of the aspect data was made to determine the RCS when the aircraft was directly head-on. This condition is difficult to establish, however, because the aircraft appears not to be aligned with the velocity vector in elevation. In other words, although the nose of the aircraft may be pointed at the radar, a plot of range vs altitude is not a straight line. The elevation aspect for the lower numbered data runs (1092 to 1101) is generally positive, indicating the beam is impinging on the top of the aircraft. For runs between 1102 and 1108 the angle is generally close to 0 degrees until the landing gear is retracted; at this time the elevation angle becomes negative and then passes through zero to a positive value at the end of the data run. In general the azimuth aspect did not vary more than 1 degree during the data runs.

A trend appears in the X_{LL} data which correlates with the elevation-angle variation. In Table 4 the RCS is seen to increase by about 3 dB after Run 1101. For this and preceeding runs the line of sight was on top of the aircraft. The same effect is seen in Table 4 for the

S-band data. L-band data for the dive courses are probably influenced by multipath and were not examined in detail. Table 2 lists the ±2.0-degree cells, and the effects of elevation angle, although not as obvious, appear. In general the amplitudes are slightly less for the 1092-to 1101 run group for the X_{LL} data. Run 1104 was the best of the dive courses, with the aspect angles close to 0 degrees for most of the run.

ACKNOWLEDGMENTS

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APPENDIX A
RADAR SYSTEM

The measurement system consists of four similar pulse radars operating from a common pedestal. Figure A1 is a view of the on-site equipment, and Table A1 shows some of the basic system characteristics. In operation all transmitters are pulsed simultaneously; the L- and S-band systems use coaxial feeds operating into a single dish, while the C- and X-band systems use separate 48- and 32-in. antennas. To change the polarization of the L-S band antenna, a physical rotation of the feed through 90 degrees is necessary. The control of the transmitted polarization for C and X bands is accomplished remotely by switching the excited port of a dual-mode transducer and by rotating a quarter-wave plate.

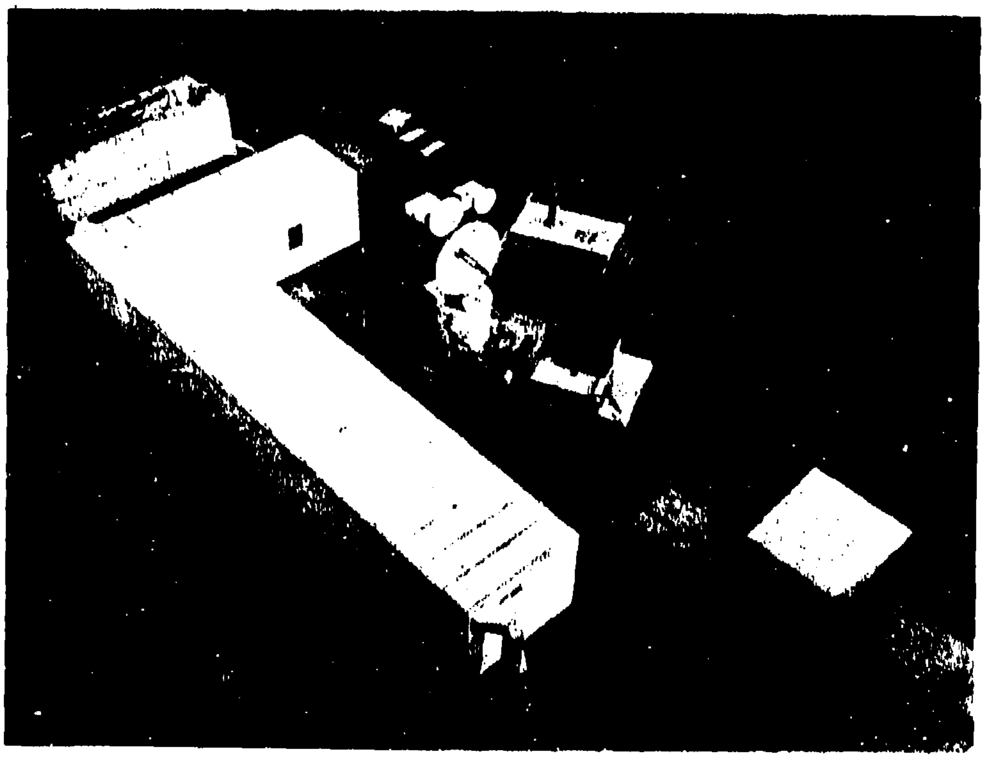

Fig. A1 — A view of the on-site equipment

Table A1
Basic System Characteristics

Band	Frequency (MHz)	Peak Radiated Power (kW)	Pulse Width (μs)	Pulse Rate (Hz)	Beamwidth, (EXH plane) (deg)	Transmitted Polarization	Received Polarization
L	1300	250	1	500	7.5 × 6	H, V	Same as transmitted
S	2800	250	1	500	3.5 × 3	H, V	Same as transmitted
C	5500	250	1	500	3 × 3	RC, LC, H, V	Simultaneous reception of parallel and orthogonal components
X	9225	250	1	500	3 × 3	RC, LC, H, V	

Shown in the photograph, mounted between the C- and X-band reflectors, is an X-band monopulse receiver. It employs a four-horn cluster and is polarized at 45 degrees so that, regardless of the transmitted polarization, sufficient signal is available for operation. The monopulse system is used exclusively for initial acquisition of the target.

A basic block diagram for either the L- or S-band system is shown in Fig. A2. The hybrid duplexer consists of a 3-dB coupler arranged so that half the generated power is radiated and half is absorbed in a load. This arrangement permits connection of the receiver to a terminal of the coupler which is isolated from the transmitter by about 30 dB. With this degree of isolation the transmit-receiver (TR) tube used for mixer crystal protection deionizes rapidly and thus permits close-in target tracking. With the present system, data can be taken within the interval of 2000 to 20,000 yd, although the measurements contained in this report were limited to a 10,000-yd. maximum range. The receiver system uses no agc and operates with a linear instanteous dynamic range of 40 dB; however, much more than this range is needed to handle most targets, especially when the 10:1 range interval is employed. A switched attenuator system is used to extend the range of the receiver. As shown in Fig. A2, a series of fixed attenuators is controlled by the video output level and stepped in 5-dB increments from 0 to 65 dB, providing a total measurement range of 105 dB. Local-oscillator power is supplied by fixed oscillators rather than by a klystron system using afc. The overall passband of the receiver is flat within ±1/2 dB over 5 MHz. A block diagram of the microwave portion of the C- or X-band system is shown in Fig. A3. The IF sections are identical for all bands.

System checkout consists of a warmup period followed by an extensive check and adjustment of all functions, including calibration of RF and IF attenuators, transmitter and local oscillator frequencies, data-system calibration, receiver sensitivity, and antenna-mount servo. RF signals during checkout are furnished by a calibrated remote beacon, so that system sensitivities are brought to the same point for each aircraft flight. Final system calibration is accomplished before and after a flight (one fuel load) by tracking a 6-in. balloonborne sphere.

Digital recordings of the pulse-to-pulse backscatter signals are employed to facilitate the reduction process. Detected video from the six receivers is stretched, quantized to ten bits, and recorded on a 1-in., 16-track recorder. Coordinating data, specifically range, azimuth, elevation, and run number, are recorded on the same tape at a rate which is 1/10 the radar

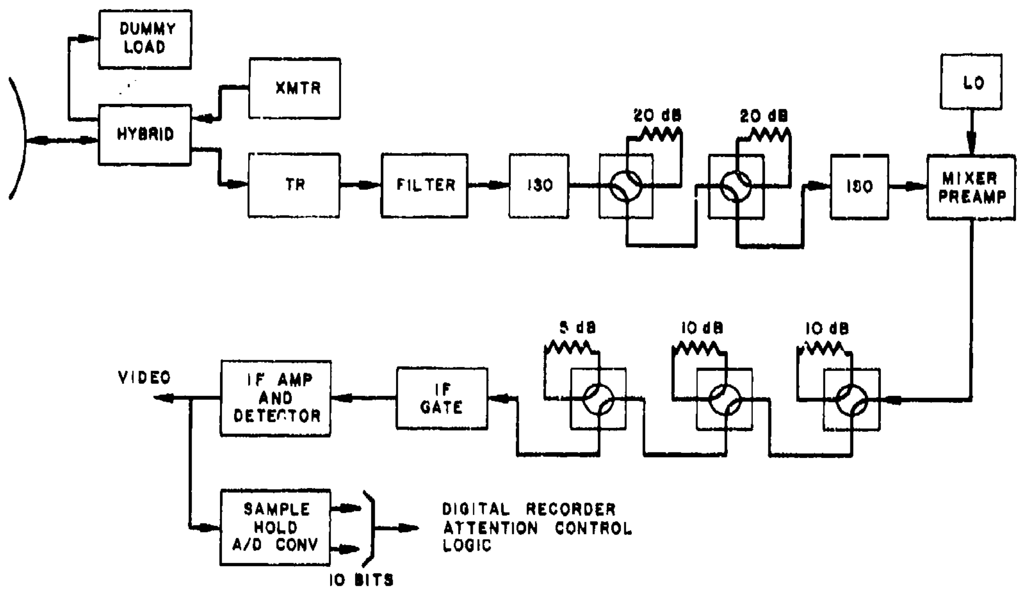

Fig. A2 — The L- or S-band system

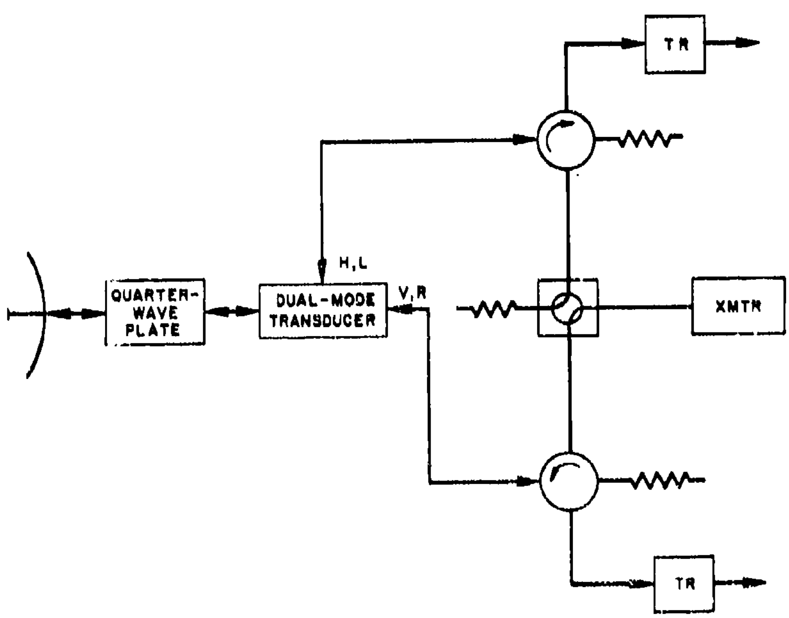

Fig. A3 — The microwave portion of the X-band system

repetition rate. In addition each radar trigger is counted and recorded for use in the tape search system in the laboratory reformatting process. Attenuator values are recorded in the bit locations for video data during the time of a change in value of attenuation.

Additional recordings consist of 16-mm boresight film, a chart recording of the detected stretched video, and a simultaneous voice commentary from all operations' stations.

APPENDIX B

DATA REDUCTION

The determination of target aspect angle is the foremost problem encountered in dynamic measurements. It was a project objective that no special cooperative measurements be performed aboard the aircraft, since it was felt that this constraint tended to expedite the measurement of operational types of targets. Moreover, since radar cross-section values at any discrete azimuth and elevation angle are virtually meaningless, some angular-aspect interval or cell must always be selected. The measurements in general represent the cross section over an angular aspect of 10 by 10 degrees. The method used in determining the aspect angle results in an accuracy of ±2 degrees. Range, azimuth, and elevation coordinates of the radar track were sampled twice a second during the laboratory reformatting process and recorded on magnetic tape. This step permits direct entry to a digital computer for the necessary smoothing and coordinate-transformation calculations. The calculation assumes that the aircraft is aligned with its velocity vector and that the flight does not include banking. The latter condition assured that the QV axis of the aircraft-oriented coordinate system (Fig. B1) was parallel to the ground. By choosing straight-line courses, banking was minimized and the requirement fulfilled. The problem of crabbing (aircraft's correction for crosswind) was normally not serious; however during some data runs angles reported by the pilot approached 7 degrees, and appropriate corrections were made to the flight plan to eliminate crab angles.

Most data are reduced by a high-speed digital computer. The reduction process (Fig. B2), is in four steps, which are linked by input-output data. The first step in the process is the determination of the aspect of the target aircraft. The input data consist of the target position in spherical radar-oriented coordinates sampled twice a second. The position data and target flight constraints are transformed to a new coordinate system erected at the target position*. Once the transformation is complete, the aircraft aspect with respect to the radar line of sight is established in the target-oriented system. The azimuth and elevation aspect as a function of time is then printed via line printer and recorded on magnetic tape for use in later steps in the processing.

The second step in the processing is the generation of a magnetic tape containing pulse-to-pulse radar cross sections. The data inputs to the computer are a magnetic tape containing voltage amplitudes for four data channels and coded levels for the step attenuators at each of the four frequencies, a magnetic tape containing aspect data, and punched cards containing various calibration factors and information for evaluation of the data. The voltage values are corrected to a 0-dB level by removing step attenuation values present at the time of measurement and calibrated to an absolute cross-section value. Calibration factors are determined by computer processing of four 2-second samples of the return from 6-in. calibration spheres to obtain the final calibration factor. The final result of this part of the analysis is pulse-to-pulse cross section as a function of time on a magnetic tape. This tape now becomes an input to the next step in the processing.

* I.D. Olin, "Aircraft Aspect Solution in Dynamic Radar Area Measurement," NRL Report 6194, Feb. 1965.

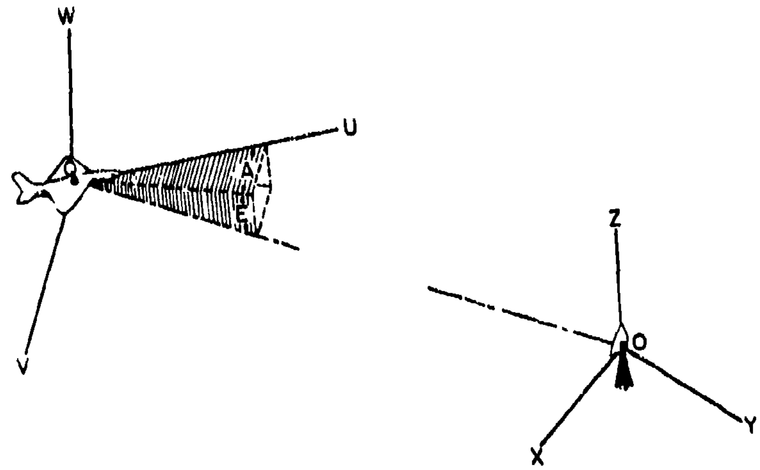

Fig. B1 — Coordinate systems about the radar O and the aircraft Q used in determining the aircraft aspect angles A and E with respect to the radar line of sight

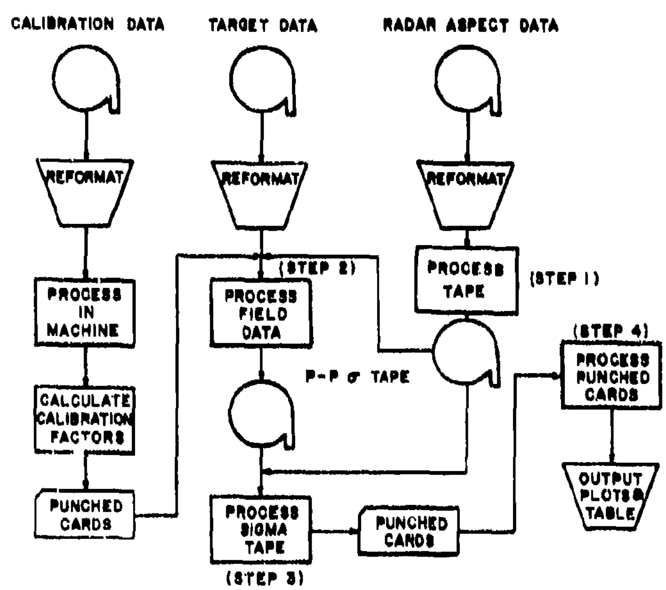

Fig. B2 — Data reduction process

The third step in processing the radar cross-section profile is the subdivision of the data satisfying aspect-cell requirements and the determination of the 20, 50, and 80 percentiles of the cross-section distribution. The inputs are the aspect information from the first part of the processing and the cross-section tape from the second part of the processing. The aspect information is examined, and a set of indices is determined to block the data. Using these indices, the cross-section data are blocked according to aspect cells, and the amplitude distribution function is determined for each aspect cell. From the distribution function the percentiles of interest are determined and held for printing. In addition to printing, the three percentiles are punched on cards together with the number of amplitude values used in forming the distribution function. These punched cards serve as input to the final step in the processing.

The final step in the processing is the compilation of all results for a single polarization. This is done by a computer routine which accepts punched cards containing percentile values and aspect-cell identification, sorts according to aspect cell, compiles the percentiles from like cells, and plots the final answer. This compilation is an averaging procedure in which each value is weighted according to the number of samples from which it was determined.